ADAPTIVE PERSONAL REPEATER

CROSS-REFERENCE TO RELATED APPLICATIONS

[01] This is the first application filed for the present invention.

MICROFICHE APPENDIX

[02] Not Applicable.

TECHNICAL FIELD

[03] The present application relates to wireless access networks, and in particular to an adaptive personal repeater for enabling a wireless subscriber to improve wireless services within a personal wireless space.

BACKGROUND OF THE INVENTION

[04] In the modern communications space, wireless access networks are increasingly popular, as they enable subscribers to access communications services without being tied to a fixed, wireline communications device. Conventional wireless access network infrastructure (e.g., base stations) is typically "built out", by a network services provider, using a network-centric approach. Thus the build-out normally begins with major Metropolitan Service Areas (MSAs) using base stations located at the center of overlapping coverage areas or "cells". The build-out, and corresponding wireless communications services, subsequently migrates outward from the MSAs to areas of lower population/service densities (e.g., urban to suburban to rural, etc.). At some point, usually dictated by economics, the build-out slows and/or becomes spotty leaving many individual wireless subscribers with unreliable or non-existent service.

[05] On-frequency repeaters are known in the art for improving wireless services within defined regions of a wireless network (e.g. within a building or a built-up area). Such on-frequency repeaters are typically provided by the wireless network provider in order to improve signal quality in high noise or attenuation environments, where signal levels would otherwise be too low for satisfactory quality of service. In some cases, a wireless network provider may install a repeater in order to improve service in an area lying at an edge of the coverage area serviced by a base station, thereby effectively extending the reach of the base-station.

[06] Prior art repeaters are part of a network-centric view of the wireless network space, in that they are comparatively large systems provided by the network provider in order to improve wireless service to multiple subscribers within a defined area. As such, they form part of the network "build-out plan" of the network provider. These systems suffer the disadvantage in that an individual subscriber cannot benefit from the improved services afforded by the repeater unless they happen to be located within the coverage area of the repeater. However, there are many instances in which wireless subscribers may reside or work in areas where the coverage area of the wireless network is unreliable. Typical examples include mobile subscribers, and subscribers located in suburban and rural areas. Also, in-building coverage can be unreliable even within MSAs, depending on the size, location and construction of buildings and/or other obstacles. In such cases, it may be uneconomical for a network provider to build-out the network to provide adequate coverage area, thereby leaving those subscribers with inadequate wireless services.

[07] Accordingly, a method and apparatus that enables an individual subscriber to cost-effectively access high quality wireless communications services, independently of the location of the subscriber, remains highly desirable.

SUMMARY OF THE INVENTION

[08] An object of the present invention is to provide an apparatus that enables an individual subscriber to cost-effectively access high quality wireless communications services, independently of a location of the subscriber.

[09] Accordingly, an aspect of the present invention provides a repeater adapted to transparently mediate signaling between a wireless communications device and a wireless communications network. The repeater comprises a Directional Donor Unit (DDU) and a Subscriber Coverage Unit (SCU). The DDU is adapted to maintain a network link with a transceiver (base station) of the wireless communications network. The SCU is adapted to maintain a local link with the wireless communications device within a personal wireless space of the repeater. The SCU generally includes, means for detecting respective uplink and downlink channel frequencies of the wireless communications device, and control means adapted to control at least the SCU to selectively receive and transmit signals within the detected uplink and downlink channel frequencies.

[10] The DDU and SCU are preferably provided as highly integrated antenna/amplifier units coupled together by a bi-directional signal path, such as a coaxial cable. In this arrangement, the total APR gain can be divided between the DDU and the SCU, so that a separate gain and system control unit is not required. Additionally, division of

system gain between the DDU and SCU also enables high-performance on-frequency repeater functionality to be obtained without the use of high-cost components, and at the same time facilitates isolation between the system antennas.

[11] Another aspect of the present invention provides a method by which a network service provider can provide wireless communications services to a subscriber or a collocated group of subscribers located in an area that is poorly serviced by a wireless communications network. Rather than build-out the network with high-cost equipment, in accordance with the present invention, the network service provider can provide the subscriber(s) with a personal repeater adapted to transparently mediate signaling between wireless communications devices of the subscriber(s) and a base station of the wireless communications network. This provides the network service provider with a cost-effective means of addressing service quality issues on an individual subscriber basis, in areas where network build-out is uneconomical.

[12] Another aspect of the present invention provides a method by which a third-party vendor can enable subscribers located in an area that is poorly serviced by a wireless communications network to access wireless communications services of the wireless communications network. Thus the third-party vendor can provide the subscriber(s) with a personal repeater adapted to transparently mediate signaling between a wireless communications device of the subscriber and a base station of the wireless communications network. Because the personal repeater is transparent to both the wireless communications network and the subscriber's wireless communications device, the

subscriber(s) can install and operate the personal repeater independently of the network service provider, without any adverse impact on operation of the base station.

[13] The APR of the present invention represents a Subscriber-Centric Technology (SCT), in that it complements existing wireless communications networks (such as cellular and PCS networks) by providing a cost-effective product solution for the individual subscriber who has inadequate or non-existent wireless coverage. The Adaptive Personal Repeater (APR) of the present invention allows the wireless subscriber or collocated group of subscribers to access the wireless communications network by reaching back from the outside of the reliable network without the need for any further network-centric build out. Thus the APR provides the subscriber with a means to address poor or non-existent coverage when, and where, they need it, and thereby empowers the individual subscriber to manage their own "personal wireless space".

BRIEF DESCRIPTION OF THE DRAWINGS

[14] Further features and advantages of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[15] Fig. 1 is a block diagram schematically illustrating an Adaptive Personal Repeater in accordance with an embodiment of the present invention;

[16] FIG. 2 is a block diagram schematically illustrating principle elements of the Adaptive Personal Repeater of FIG. 1;

[17] FIG. 3 is a block diagram schematically illustrating principle elements of an exemplary directional donor unit (DDU) usable in the embodiment of FIG. 2;

[18] FIG. 4 is a block diagram schematically illustrating principle elements of an exemplary subscriber coverage unit (SCU) usable in the embodiment of FIG. 2;

[19] FIG. 5 is a block diagram schematically illustrating principle elements of an exemplary downlink AGC usable in the SCU of FIG. 4;

[20] FIG. 6 is a block diagram schematically illustrating principle elements of an exemplary uplink AGC usable in the SCU of FIG. 4;

[21] FIG. 7 is a state diagram illustrating exemplary states and state transitions traversed during operation of the Adaptive Personal Repeater of FIG. 1; and

[22] FIG. 8 is a flow chart illustrating principle operations of an exemplary adaptive control algorithm during initialization and operation of the Adaptive Personal Repeater of FIG. 1.

[23] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[24] The present invention provides an Adaptive Personal Repeater (APR) 2, which enables cost-effective delivery of high quality wireless communications services to subscriber(s) located outside a reliable coverage area of an existing wireless communications network 4. In general,

the APR 2 operates to create a personal wireless space 6 encompassing the subscriber's wireless communications device(s), and "reaches back" into the reliable coverage area of the wireless communications network 4 in order to access wireless communications services. FIG. 1 is a block diagram schematically illustrating operation of the APR 2 in accordance with the present invention.

[25] As shown in FIG. 1, a conventional wireless communications network 4 comprises a plurality of base stations 8, each of which provides wireless communications services within a respective coverage area or cell 10. Mobile communications devices (not shown) within a cell 10 access wireless communications services of the network 4 by negotiating a wireless connection with the respective base station 8 of the cell 10, in a manner known in the art. The size and shape of each cell 10 may be irregular, and will depend on many factors, including, for example, distance from the respective base station 8, and the presence of obstacles (e.g. buildings and geographical features such as hills, valleys etc.) which tend to attenuate radio signals. Within a multi-cell network 4 such as shown in FIG. 1, inter-cell boundaries 12 are determined as the point at which a mobile communications device is switched or "handed-off" from one base station 8 to a base station 8 of an adjacent cell 10. Typically, this is determined on the basis of signal power. At the edge of the wireless communications network 4, the cell boundary corresponds with the network coverage area boundary 14, which may nominally be determined as the point at which the signal-to-noise (S/N) ratio becomes too low to permit negotiation of a satisfactory connection between the nearest base station 8 and a mobile communications device.

[26] Within each cell 10, the quality of wireless service access may vary widely. For example, within a built-up area, multiple reflections from the surfaces of buildings can create a high-noise or attenuation environment which degrades reliability of access to the wireless communications network. Within buildings, both signal scattering and attenuation can prevent reliable access to the wireless communications network.

[27] The Adaptive Personal Repeater (APR) 2 of the present invention operates to define a personal wireless space 6 for the subscriber(s), and reaches back to a base station 8a to enable the subscriber(s) to reliably access the wireless communications services of the network 4. The personal wireless space 6 may be defined within a poorly served area of the wireless network 4 (e.g. within a building or other high noise/attenuation area) or, as shown in FIG. 1, in an area beyond the network coverage area boundary 14. In either case, the APR 2 is functionally positioned between the base station 8a and the subscriber's Wireless Communications Device(s) (WCD) 16. The subscriber's WCD(s) 16 may take the form of any conventional wireless communications device, such as, for example, Personal Digital Assistants (PDA's), wireless telephone handsets, pagers, and one and two-way messaging devices.

[28] Between the APR 2 and the base station 8a, a network link is established, in which respective uplink and downlink channel power levels are detected and adjusted in order to optimize performance of the link. Similarly, between the APR 2 and the subscriber's mobile communications device 16, a local wireless link 20 is established, in which respective uplink and downlink

channel power levels are detected and adjusted as will be described in greater detail below. However, the APR 2 does not terminate any connections intermediate the base station 8a and the subscriber's mobile communications device 16, and does not perform any signal format or communications protocol conversions. Accordingly, the APR 2 is functionally transparent to both the network and conventional mobile communications devices, and thereby enables protocol- and signal format-independent interaction between the base station 8a and the subscriber's mobile communications device 16. Once the respective links 18, 20 between the APR 2 and the base station 8a, and between the APR 2 and the WCD 16 have been set up, and respective up-link and down-link channel powers negotiated, the APR 2 operates to transparently facilitate signaling between the WCD 16 and the base station 8a. Thus the WCD 16 interacts with the base station 8a to negotiate communications links (e.g. protocols, signal formats, time slots etc.) in a conventional manner, so that wireless communications services of the network 4 can be seamlessly accessed by the subscriber using the WCD 16. However, as described in greater detail below, the transmit and receive performance of the APR 2 exceeds that of a conventional mobile communications device, thereby enabling a connection between the WCD 16 and the base station 8a to be established over a greater distance and/or in a higher noise/attenuation environment than would be possible if the WCD 16 were communicating with the base station 8a directly. Moreover, the APR adaptively maintains a reliable link between the WCD and the base station.

[29] The APR 2 of the present invention is an "on-frequency" repeater, in that uplink and downlink RF signals are conveyed through the APR 2 without altering the

respective channel frequencies. In operation, transmissions from the subscriber's WCD(s) 16 are detected by the APR 2, which then adapts to the RF characteristics of the subscriber's WCD(s) 16 by acquiring appropriate uplink and downlink channel frequencies. Thereafter, the APR 2 operates to selectively receive, amplify, and retransmit RF signals within these uplink and downlink channel frequencies.

[30] FIGs. 2-6 schematically illustrate principal elements of an APR 2 in accordance with an embodiment of the present invention. As shown in FIG. 2, the APR 2 generally comprises a Directional Donor Unit (DDU) 22 and a Subscriber Coverage Unit (SCU) 24. The DDU 22 and SCU 24 may be integrated into a single device, or may be provided as separate components suitably coupled to each other (e.g. via a coaxial cable or the like). For ease of description, each of the DDU 22 and SCU 24 are described below as separate devices coupled together by a suitable connection path 26 (e.g. a coaxial cable connection).

[31] In the illustrated embodiment, each of the DDU 22 and SCU 24 are provided as highly integrated units, which co-operate to implement the entire functionality of the APR 2. As described below, this arrangement improves performance, lowers cost and eliminates the need for an electronic unit separate from the antennas to house the repeater's functional building blocks.

[32] Conventional On-Frequency Repeaters (OFRs) generally comprise one or more power amplification and control units connected to two passive antennas via respective lengths of coaxial cable. These electronic units are usually located at some distance from the passive

antennas, requiring the need for expensive coaxial cable to minimize losses and maintain isolation between each unit and the antennas. Also, because even expensive coaxial cables have some amount of loss, expensive high performance building blocks, such as highly linear power amplifiers are required to overcome the loss and meet the system performance specifications. High performance functional blocks and high grade cables are necessary to meet not only the transmit power requirements, but to preserve the receive signal quality as well. Since OFRs are non-frequency translating and the system gain within the unit can approach 100 dB, the possibility of internal system instabilities are high. Thus, it is frequently necessary to implement separate shielding for all internal building blocks, typically by using expensive multiple aluminum enclosures within each electronic unit.

[33] In the illustrated embodiment, the functionality of the APR 2 is provided by two highly integrated units, each of which provides a portion of the system gain necessary to meet the repeater's overall performance requirements. As will be described in further detail below, this division of system gain substantially reduces the need for high performance (and thus expensive) components and high shielding requirements within each unit.

[34] In accordance with the present invention, the DDU 22 and SCU 24 implement a technique of Adaptive Interference Mitigation, in which RF interference in the subscriber's personal wireless space 6 is mitigated by a combination of one or more of: physical antenna separation; cross polarization; RF power management; and the use of a narrow beam network link 18 between the APR 2 and the base station 8a. Interference has become a problem in most

wireless service networks. The type and degree of interference varies from one network to the other. So-called "Smart" antenna technology has been used in a wide variety of applications to combat interference in these networks. This smart antenna technology can be effectively applied at a base station to reduce the interference problem for both the downlink (interference to the handset from other base stations) and the uplink (interference to the base station from other handsets) communication paths. However, smart antenna technology has not been used to mitigate interference occurring at the handset end of the link. This is largely due to the size and power constraints of the handset, and the requirement that the handset antenna must be omni-directional to successfully connect to, and communicate with the base station in a wide area network.

[35] The APR 2 of the present invention provides a means to mitigate interference at the handset end of the network for both the downlink and the uplink propagation paths. The APR 2 operates to transform the handset's omni-directional antenna pattern of the WCD 16(for the local wireless link 20, which is confined to a small area of reliable coverage) into a directional antenna pattern (of the network link 18) by masking over the weak handset signal with a strong conditioned signal in a specific direction. Additionally, the APR 2 adaptively provides continuous interference mitigation within the subscriber's personal wireless space 6, and minimizes any possible interference that may be generated, by confining the size of the personal wireless space 6 to only the subscriber's position.

[36] Directional antennas radiate RF energy in one direction more than in other directions. The APR 2 uses an external directional antenna to reach back into the network and radiate RF power to the base station 8a from the subscriber's personal wireless space 6. By virtue of the directionality of the antenna, the subscriber's personal wireless space 6 not only can discriminate against interference coming from outside the antenna's beam-width, but also can prevent generating possible interference to other base stations 8 in other directions. This in itself passively mitigates the interference in both the downlink and uplink paths. The antenna's discrimination provides the means to spatially separate the desired signal from possible sources of interference from other base stations. With this discrimination in hand, the APR 2 then amplifies and conditions the desired signal and adaptively transmits it to ensure that at the WCD 16, the desired signal remains relatively constant in level regardless of the subscriber's position or movement within the personal wireless space 6. Unlike conventional mitigation schemes, where the interference is reduced relative to the desired signal or itself, the APR 2 operates to increase the desired signal level relative to the interference within the subscriber's personal wireless space 6.

[37] The DDU 22 operates to establish and maintain the network link 18 between the APR 2 and the base station 8a of the wireless communications network 4. As is known in the art, signal attenuation within such a wireless link 18 is generally a function of distance between the base station 8a and the DDU 22. Accordingly, the DDU 22 preferably enables the APR 2 to maintain a connection with the base station 8a over a wide range of receive and transmit power levels. The DDU 22 may, for example, be

advantageously designed to receive downlink signal power levels to as low as -120dBm. Additionally, the DDU 22 may be designed to transmit uplink signals to the base station to as high as +37dBm, which will typically be on the order of 10dB greater than that of conventional cellular handsets. This transmit and receive performance of the DDU 22 enables maintenance of the network link 18 with the base station 8a, even when the DDU 22 is located well beyond the conventional cell (and network coverage area) boundary 14.

[38] In the embodiment illustrated in FIG. 2, the Directional Donor Unit (DDU) 22 is provided as a single port active antenna comprising a Directional Donor Antenna (DDA) 28 integrated with a Transceiver Diplexer (TRD) 30. A bi-directional port 32 couples the DDU 22 to the SCU 24 through the coaxial cable connection 26.

[39] In the illustrated embodiment, the DDA 28 is provided as a high performance, vertically polarized, directional antenna. The DDU 22 is positionable (i.e. rotatable in a horizontal plane) to allow for alignment of the DDA 28 to the base station 8a during installation. Directionality of the DDA 28 helps to fine tune positioning. Vertical polarization maximizes coupling to the typically vertical electro-magnetic (EM) field of the (conventional) base station 8a.

[40] The DDU 22 can beneficially be designed for outdoor use. In such cases, fewer components with better temperature ratings can be used in this unit to implement the functional performance requirements of the DDU 22 while keeping costs down. The DDU 22 components may, for example, represent less than 20% of the APR's total

component count, all of which are designed to operate in an outdoor environment. The DDU 22 may also include a low-cost plastic enclosure that protects the functional components from the outdoor elements. This enclosure houses an integrated high gain antenna and Transceiver Diplexer (TRD) on a common Printed Wiring Board (PWB). As part of the TRD, a low noise amplifier is used to preserve the downlink receive signal quality, while a power amplifier delivers the necessary power in the uplink path. Since both devices are connected directly to the integrated antenna via a diplexer, the system performance is maximized while keeping component costs comparatively low. This means that the low noise amplifier and power amplifier requirements can be relaxed by 3 to 5 dB in comparison to conventional OFRs so that costs are significantly lower. Performance is enhanced by virtue of little or no loss between the antenna and the diplexer. Also, the system reliability can be improved by using lower power devices. The DDU gain for both the uplink and the downlink paths can be less than 40 dB, keeping isolation requirements within the unit moderately low. Consequently, individual components or building blocks do not require separate aluminum enclosures for shielding, but rather the uplink and downlink paths can be separated and the building blocks shielded together as functional sections, using simple board-level shields to increase isolation and prevent circuit coupling of unwanted high-level signals. Since the DDU 22 sets the system Noise Figure (NF) of the APR 2 in the downlink path, and provides the necessary gain for a given input to produce a +37 dBm EIRP output in the uplink path, the loss of the coaxial cable 26 can be relatively high, without adversely affecting the system performance. For this reason, in comparison with conventional OFR

systems, a much lower grade cable (e.g. RG58 verses ½ inch heliax) can be used, hence the cost of the cable can be very low by comparison (e.g. by a factor of 10 or more for a given length). Lower cost cable usually means a much smaller cable diameter, which greatly improves ease of installation by allowing for a tighter bend radius. Also, because the isolation requirements are lower, the shielding of the cable is not as critical.

[41] In operation, the DDA 28 simultaneously transmits uplink RF signals and receives downlink RF signals through the network link 18. For example, the DDA 28 may be designed to transmit uplink RF signals within a frequency band from 824 to 849 MHz and receive downlink RF signals within a frequency band from 869 to 894 MHz. A 12 dBi antenna gain is required to transmit a maximum EIRP of +37 dBm in the uplink path for a +25 dBm TRD output.

[42] The bi-directional port 32 simultaneously receives and transmits both uplink and downlink frequency bands through the coaxial connection 26. For example, the port 32 may be designed to receive uplink RF signals from the SCU 24 within the uplink frequency band of 824 to 849 MHz and transmit downlink RF signals to the SCU 24 within the downlink frequency band of 869 to 894 MHz.

[43] As shown in FIG. 3, the TRD 30 comprises respective uplink and downlink signal paths 34, 36 connected between a DDA diplexer 38 coupled to the DDA 28, and a TRD port diplexer 40 coupled to the port 32. The DDA diplexer 38 operates to separate the signal paths 34, 36 at the DDA 28. Similarly, the TRD port diplexer 40 operates to separate the signal paths at the port 32. The respective TRD port and DDA diplexers 38, 40 also operate to define and limit

the frequency band(s) over which the system must maintain stability.

[44] In the illustrated embodiment, the uplink path 34 comprises: a two-stage driver 42 including a pair of series connected driver amplifiers 44a and 44b; and a power amplifier (PA) 46 connected in series with the two-stage driver 42. This arrangement of cascaded driver and power amplifier circuits connected directly to the DDA via the DDA diplexer 38 reduces output power requirements of the PA 46. For example, the output power of the PA 46 at the DDA 28, which may be automatically controlled (i.e. enabled or disabled) by a simple detection circuit 48, can be approximately 3 dB lower than the equivalent output power of a conventional cellular handset. This arrangement minimizes losses between the PA 46 and the DDA 28; improves performance, power consumption and reliability; while at the same time lowering cost.

[45] The two-stage driver 42 and the power amplifier 46 within the uplink path 34 facilitate automatic RF power management, and so allows the DDU 22 to reliably maintain the network link 18 with the base station 8a. This operation is simplified by the fact that the propagation environment of the network link 18 is comparatively static due to the fixed locations of the base station 8a and the DDU 22. Reliable maintenance of the network link 18 can thus be achieved by measuring the power of downlink RF signals received from the base station 8a, and using the measured power to control the signal power of uplink RF signals transmitted to the base station 8a. For example, if the measured power of the received downlink RF signals is greater than a predetermined minimum threshold, then the uplink RF signal transmit power can be reduced to improve

spectrum efficiency, conserve energy, increase reliability and reduce system gain. Conversely, if the measured power of the received downlink RF signals drops below the predetermined minimum threshold, then the uplink RF signal transmit power can be increased to improve the signal-to-noise ratio. In the illustrated embodiment, control of the uplink RF signal transmit power in this manner is accomplished within the SCU 24, as will be described in greater detail below. It will be appreciated, however, that uplink RF signal transmit power control may be effected within the TRD 30 using a suitable cross-over circuit (not shown) in which, for example, the PA 46 is provided as a variable gain amplifier controlled by a controller unit coupled to the downlink path 36 to detect the received downlink RF signal power.

[46] To further improve the reliability of the PA 46, an isolator 50 may be placed in series between the PA 46 and the DDA diplexer 38 to prevent reflected power from appearing at the output of the PA 46 (due, for example, to any mismatch between the DDA 28 and the DDA diplexer 38). Additionally, the isolator 50 can provide constant impedance matching for the DDA diplexer 38 when the PA 46 is enabled and disabled. As may be appreciated, frequency crossover noise may contaminate the uplink RF signal in the uplink path 34. Such frequency cross-over noise is attenuated by the DDA and port diplexers 36, 38. Further attenuation of frequency crossover noise within the uplink path 34 may be accomplished using an uplink Band Pass Filter (BPF) 52, connected in series between the two driver stages 44a and 44b. Isolation of the DDA diplexer 38 prevents the PA 46 from saturating the downlink path amplifiers (described below). This isolation is critical

because the transmit power from the PA 46 into the DDA diplexer 38 can be as high as +28 dBm.

[47] The downlink path 36 generally comprises a Low Noise Amplifier (LNA) 54, a downlink band pass filter (BPF) 56, and a downlink signal driver 58 connected in series between the DDA diplexer 38 and port diplexer 40. The LNA 54 is preferably a high performance amplifier providing, for example, 15 dB of gain with a noise figure of about 1.5 dB. The LNA gain and noise figure, in combination with the DDA 28 gain and losses in the DDA diplexer 38, determine the minimum signal strength and quality (i.e. signal-to-noise [S/N] ratio) of received downlink RF signals. For example, in the illustrated embodiment, a received downlink RF signal of -120 dBm in a 25 kHz noise bandwidth yields a S/N ratio of +17 dB at the output of the bi-directional port 32, excluding any environmental noise.

[48] The downlink BPF 56 (which may, for example, be a SAW BPF) operates to reject both image and frequency crossover noise, and further attenuates any uplink RF signal in the downlink path 36. The downlink signal driver 58 is conveniently provided as an amplifier which operates as a buffer and gain stage to compensate for losses in the (coaxial cable) connection 26 between the DDU 22 and SCU 24. Because cable losses in low-cost coaxial cable tend to be relatively high, it is preferable to amplify the received downlink RF signal upstream of the connection 26, and thus before the loss is incurred, to preserve the S/N ratio established by the DDA 28, LNA 54, and DDA diplexer 38.

[49] Total APR gain is the summation of both the DDU 22 and SCU 24 gains minus the losses in the coaxial cable connection 26, and may be limited by the isolation between the units achieved during installation. The DDA 28 preferably has a front to back ratio of greater than 25 dB to help maximize the isolation between the two units, and therefore achieve sufficient APR gain to maintain a reliable network link 18.

[50] Referring back to FIG. 2, the Subscriber Coverage Unit (SCU) 24 operates to create the subscriber's personal wireless space 6 by maintaining the local wireless link 20 between the APR 2 and the subscriber's WCD(s) 16. As with a conventional cell 10 of the wireless communications network 4, the subscriber's personal wireless space 6 may be irregular in shape. However, the coverage area will not only be determined as a function of RF signal power and/or signal-to-noise ratio of uplink RF signals received by the SCU 24, but also as a function of the position of the subscriber's WCD 16 relative to the SCU 24. In all cases, it is anticipated that the coverage area of the subscriber's personal wireless space 6 will be very much smaller than a conventional cell 10 of the wireless communications network 4. For example, in some embodiments, it is expected that the subscriber's personal wireless space 6 will extend 25m (or less) from the SCU 24. Such embodiments are particularly suited for enabling the subscriber to access wireless communications services of the network 4 from, for example, any location in and about their residence or place of business. Other embodiments may provide a larger or smaller personal wireless space 6, if desired.

[51] In any event, it is preferable for the subscriber's WCD 16 to operate at a minimum signal transmission power. Thus the SCU 24 implements a technique of Adaptive Coverage Breathing (ACB), such that the coverage area of the subscriber's personal wireless space 6 is automatically adjusted in order to ensure acceptable signal-to-noise ratio in both the uplink and downlink paths of the local link 20, while at the same time minimizing transmission (i.e. uplink RF signal) power in the WCD 16.

[52] In general, Adaptive Coverage Breathing (ACB) comprises a technique of RF power management that allows the coverage area of the subscriber's personal wireless space 6 to "breathe" by adaptively expanding and contracting to the position of the subscriber's WCD 16 relative to the SCU 24. This allows both the subscriber's WCD 16 and the SCU 24 to radiate only the necessary powers needed to maintain reliable signaling over the local link 20. As the subscriber's WCD 16 moves relative to the SCU 24, the coverage area of the personal wireless space 6 changes continuously to adapt to the movement. As the WCD 16 moves towards the APR 2, the coverage area automatically contracts, so that the personal wireless space 6 is limited to just encompass the WCD 16. This can be accomplished by measuring the signal power of uplink RF signals received from the WCD 16, and then adjusting the transmission power of downlink RF signals accordingly. If two or more wireless communications devices 16 are being used simultaneously, then the SCU 24 can operate to expand the coverage area to accommodate the WCD 16 located furthest from the SCU 24 (or transmitting the weakest uplink RF signals). This is achieved by measuring the power of uplink RF signals received from each of the wireless communications devices 16, and adjusting the

downlink transmit power to account for the difference between the measured signal power levels.

[53] Two major benefits for the subscriber resulting from the ACB concept include reduced RF radiation, and increased battery life within the subscriber's WCD 16. Reduced RF radiation for the subscriber is a major benefit, particularly in view of growing concerns that high level RF radiation in close proximity to the subscriber's body (typically the head) may be hazardous to human health. The ACB concept implemented by the present invention permits the RF power radiation of the subscriber's WCD 16 to be significantly reduced (in comparison to that required for communications within the conventional wireless communication network 4), by maintaining reliable balanced power levels in the uplink and downlink paths. Typically, the single most power-consuming section in a wireless communications device is the uplink channel RF amplifier. This amplifier is normally a class AB or C amplifier, which consumes battery power proportional to the RF input signal level. That is, a large RF input signal will cause the uplink channel RF amplifier to consume a large amount of battery power to produce the necessary uplink RF signal power through the antenna. Lowering the uplink RF signal power requirement of the WCD 16, as enabled by the present invention, significantly extends the battery life, and thus the "talk time" of the WCD 16.

[54] In the illustrated embodiment, a minimum acceptable uplink channel RF signal power of the WCD 16 is negotiated at a start of a communications session. This uplink channel RF signal power is then maintained constant (during the communications session), and the SCU 24 adapts to changes in the position of the WCD 16 by accepting widely

varying uplink channel RF signal powers from the WCD 16. With this arrangement, the variation in received uplink channel RF signal power may be as high as 50 to 60 dB, depending largely on the proximity of the WCD 16 to the SCU 24. Accordingly, the SCU 24 is preferably designed to receive uplink channel RF signal power levels varying between, for example, 0 dBm to -60 dBm.

[55] The received uplink channel RF signal power level can be measured by the SCU 24, and used to control the downlink channel RF signal power. For example, if the received power of the uplink RF signals is greater than a predetermined minimum threshold, then the downlink RF signal transmit power can be reduced (i.e. the coverage area of the subscriber's personal wireless space 6 reduced) to improve spectrum efficiency, conserve energy, increase reliability and reduce system gain. Conversely, if the measured power of the received uplink RF signals drops below the predetermined minimum threshold, then the downlink RF signal transmit power can be increased (i.e. the coverage area of the subscriber's personal wireless space 6 expanded)to improve the signal-to-noise ratio.

[56] In the illustrated embodiment, the Subscriber Coverage Unit (SCU) 24 is provided as a single port active antenna comprising a Subscriber Coverage Antenna (SCA) 60 integrated with a dual-directional processor (DDP) 62. A single bi-directional port 64 couples the DDP 62 to the TRD 30 via the coaxial cable 26. As shown in FIG. 4, the DDP 62 comprises respective uplink and downlink signal paths 66 and 68 connected between an SCA diplexer 70 coupled to the SCA 60, and a port diplexer 72 coupled to the bi-directional port 64. The SCA diplexer 70 operates to separate the signal paths 66, 68 at the SCA 60.

Similarly, the port diplexer 72 operates to separate the signal paths 66 and 68 at the bi-directional port, P2 64. The respective SCA and port diplexers 70 and 72 also operate to define and limit the frequency band(s) over which the system must maintain stability.

[57] In the illustrated embodiment, the SCA 60 is provided as a wide beam-width, horizontally polarized, directional antenna. Vertical positioning of the SCU 24 (and thus the SCA 60) provides a mechanism to improve isolation between the DDA 28 and SCA 60, as well as to optimize total APR gain. A wide beam-width of the SCA 60 ensures adequate forward coverage to create a "bubble-effect" for the personal wireless space 6. Horizontal polarization creates an orthogonal relationship to the polarization of the DDA 28, further improving isolation between the SCA 60 and the DDA 28, while increasing the field coupling between the SCA 60 and the WCD 16. System isolation is further improved by the front to back ratio of the SCA 60, which may, for example, be >10 dB.

[58] The SCU 24 can beneficially be designed as an indoor unit that incorporates the SCA 60 integrated with the dual directional processor (DDP) 62. In some embodiments, the radiating element of the antenna can be physically attached to the printed wiring board (PWB) shields, which can then serve as the reflector portion of the antenna. The DDP 62 includes two intelligent gain controllers (IGCs) 92 and 94, each sharing a common IF down-converter and narrowband detector, and being controlled by a single digital controller in accordance with an adaptive control algorithm. The number of components in the SCU 24 may, in some embodiments, account

for over 80% of the APR's total component count, all of which can be low power devices with a commercial temperature rating to satisfy the indoor environment, which in turn helps to keep costs down.

[59] The gain in the SCU 24 can be less than 60 dB for both the uplink and downlink paths. This gain is manageable in a single PWB, without the need to separately enclose the individual building blocks. As with the DDU 22, the uplink and downlink paths are separated, and the building blocks can be shielded together as functional sections using simple, conventional, board-level shields to increase isolation and prevent circuit coupling of unwanted high-level signals. The digital controller can be shielded from the RF and analog sections (also be means on conventional board-level shields), to prevent digital noise from radiating to the RF and analog sections. This simple shielding requirement helps to lower the product cost while improving the reliability by maintaining unit stability.

[60] The SCA 60 operates to transmit downlink RF signals to the subscriber's WCD 16, and receives uplink RF signals from the subscriber's WCD 16. An antenna gain of 6 dBi is required, but not limited to radiate a maximum -20 dBm EIRP in the downlink channel. Maximum EIRP, minus the antenna gain, determines the output of the DDP 62, which may, for example, be about -26 dBm.

[61] The bi-directional port 64 simultaneously receives and transmits both uplink and downlink frequency bands. For example, the bi-directional port 64 may accept downlink RF signals from the DDU 22 within a frequency band from 869 to 894 MHz, and transmit uplink RF signals to the DDU 22 within a frequency band from 824 to 869 MHz.

[62] In the illustrated embodiment, the dual-directional processor (DDP) 62 is provided as a combined RF and digital processing module. RF signals within the uplink and downlink paths 66 and 68 are separately amplified, conditioned and processed (over their entire 25 MHz bands). This processing scheme improves performance while reducing complexity, thus lowering product cost. The DDP 62 comprises: the uplink path 66 including a wideband uplink Automatic Gain Controller (AGC) 74 series connected with a slaved variable gain amplifier (VGA) 76 and an output amplifier 78; the downlink path 68 including a preamplifier 80, wideband downlink automatic gain controller (AGC) 82, a slaved variable gain amplifier (VGA) 84, and an output amplifier 86; a switched common down-converter 88; and a digital controller 90 operating under software control.

[63] The uplink path 66 interfaces with the down-converter 88 and digital controller 90 to define an uplink intelligent gain control (IGC) 92. Similarly, the downlink path 68 interfaces with the down-converter 88 and digital controller 90 to define a downlink IGC 94.

[64] As is known in the art, on-frequency repeaters can oscillate if the system gain exceeds the antenna isolation. For this reason, and depending on the required link performance, installation of on-frequency repeaters can be very difficult. In accordance with the present invention, the IGCs incorporate the concepts of Adaptive Coverage Breathing (ACB) and Coverage Area Signature (CAS) to prevent and eliminate the possibility of oscillations occurring due to system instability during installation and subsequent operation of the APR 2. The ACB concept ensures only the necessary power is transmitted in both the uplink

and downlink paths to maintain a reliable local link 20, hence the system gain is only as high as it needs to be in both paths, which ultimately increases system stability. The CAS concept provides a means to de-correlate the leakage signals that appear at the APR inputs (DDA 28 and SCA 60) from the incoming received signals. This de-correlation allows the APR 2 to separate the leakage signal from the incoming signals in order to adaptively adjust the APR gain to maintain a defined level of stability.

[65] An unconditionally stable system requires that total system isolation (comprising the front to back ratios of the DDA 28 and SCA 60; polarization loss; propagation path loss; and cable losses) must be greater than the maximum combined gain of the DDP 62 and the TRD 30. System stability within a defined band can be maintained by operation of the uplink and downlink IGCs 92 and 94 which adaptively adjust the hardware gain in the uplink and downlink paths 66 and 68 independently, so as to minimize the transmit power in both directions, via a hardware and software control algorithm. Gain reduction as a result of insufficient isolation only reduces the coverage area of the personal wireless space 6. It does not limit the ability of the APR 2 to maintain reliable links 18, 20 in both directions for the reduced coverage area of the personal wireless space 6.

[66] As part of the IGC, the down-converter 88 and digital controller 90 operate to implement a digital offset correction method which enables the output of a wideband AGC to be set for RF signals that have not captured the AGCs 74 and 82. As in known in the art, a wideband AGC will level to the highest signal that captures the AGC

within a defined bandwidth. If no signals are present, the AGC may level to the thermal and system noise of a given bandwidth. If weak desired (i.e. uplink or downlink RF) signals are present, and the AGC bandwidth is much larger than the signal bandwidth (such that noise masks the weak signals) the AGC will be captured by the noise rather than the weak desired signal. In the present invention, narrowband detection is used as a means to detect the (weak) desired signals embedded in the noise. Detection of the desired uplink and downlink signals is then used by the digital controller 90 to offset the output to which the appropriate AGCs 74 and 82 level. This same technique can also be used to detect weak desired signals in the presence of high-level unwanted signals that would otherwise capture an AGC and limit the system gain for the desired signals.

[67] As shown in FIG. 4, the down-converter 88 comprises a switching input 96, an active mixer 98, a Xtal band pass filter 100, a log amp detector 102, and a tunable synthesizer 104, which is tuned by the digital controller 90 to 45 MHz above the uplink channel frequency and 45 MHz below the downlink channel frequency. The switching input 96 is controlled by the digital controller 90 to supply an RF signal from a selected one of the uplink and downlink AGCs 74 and 82 to the active mixer 98. Similarly, the synthesizer 104 is controlled by the digital controller 90 to supply an RF synthesized signal to the mixer 98. The output of the mixer 98 is channeled by the Xtal BPF 100 and supplied to the detection log amplifier 102, which operates to detect the uplink and downlink signals within their respective channels. The output of the detection log amplifier 102 is supplied to the digital controller 90, and is used for decision making in accordance with the adaptive control algorithm. Thus

when the switching input 96 supplies an RF signal from the uplink path 66 to the mixer 98, the Xtal BPF 100 and detection log amplifier 102 operate to detect the level and number of desired signals within the uplink channel, and this information can be used by the digital controller 90 to set the appropriate power in the uplink path 66 and to tune the synthesizer 104 to the corresponding downlink channel frequency. Conversely, when the switching input 96 supplies an RF signal from the downlink path 68 to the mixer 98, the Xtal BPF 100 and detection log amplifier 102 operate to detect weak desired signals within the downlink channel, and this information can be used by the digital controller 90 to set the appropriate power in the downlink path 94. This arrangement enables the digital controller 90 to detect any number of weak desired uplink and downlink signals that are below either high-level wanted signals and/or adjacent carrier signals, or the -95 dBm system noise floor within a respective 25 MHz bandwidth. The digital controller 90 provides a digital correction to each of the AGCs 74 and 82, thereby offsetting the respective leveled outputs to the weak desired signals.

[68] The digital controller 90 comprises a micro-processor 106 operating under software control, a configuration switch 108 enabling a user to control an operating configuration of the micro-processor 106, and one or more Digital-to-Analog converters (DACs) 110 and Analog-to-Digital Converters (ADCs) 112 for enabling interaction between the micro-processor 106 and other elements of the DDP 62. The digital controller 90 operates in accordance with an adaptive control algorithm (described in greater detail below), which provides the necessary processing control for APR operation as a stand-alone unit

without intervention after the installation. It may also control APR operations during system set-up, in order to simplify installation of the APR 2.

[69] The DACs 110 accept respective digital output signals generated by the micro-processor 106, and convert these digital output signals into analog control signals which are used, for example, for setting AGC gain in both the uplink and downlink paths 66 and 68. The ADCs 112 convert analog RF signals into digital input signals, which are supplied to the micro-processor 106. During operation, the micro-processor 106 processes these input signals, under software control, to determine system parameter levels (e.g. AGC gain levels) and generate appropriate digital output signals. This processing may include comparing digital input signals to one or more predetermined threshold values, and determining the system parameter levels in accordance with the comparison result.

[70] The configuration switch 108, which may be provided as a conventional DIP switch having one or more settings, allows the subscriber to select an operating configuration of the micro-processor 106. Exemplary settings of the configuration switch includes: a "set-up" setting which may be used during installation of the APR 2; a "run" setting which may be used during normal operation of the APR 2; a carrier A/B band select setting which may be used by the subscriber to select the desired carrier. Carrier A/B bands may be selected together or individually. For example, when the configuration switch 108 is placed in the "set-up" setting, the micro-processor 106 may operate under software control to reduce AGC gain and transmission power levels to enable the subscriber to adjust the placement and positioning of the DDU 22 and SCU 24. Additionally, the

configuration switch 108 may have one or more settings by which the subscriber can choose to limit the coverage area of the subscriber's personal wireless space 6, e.g. by causing the micro-processor 106 to limit gain within the downlink path 68.

[71] The DDP downlink path 68 is preferably designed to receive, process and transmit the entire 869 to 894 MHz cellular frequency band. As mentioned above and shown in FIG. 4, the DDP downlink path 68 comprises a preamplifier 80, AGC 82, slaved VGA 84 and an output amplifier stage 86. These elements can be cascaded with a band-pass filter (BPF) 114 and inter-stage filters 116a, 116b.

[72] The preamplifier 80 operates to preserve the S/N ratio established by the TRD LNA 54, and buffers the port diplexer 72 from the first BPF 114 in the downlink path 68. This BPF 114, together with the port diplexer 72 limits the downlink bandwidth to 25 MHz, rejecting both image and frequency crossover noise and any out-of-band signals, including RF signals in the uplink path 66.

[73] The downlink AGC 82 is designed to provide substantially constant output leveling over a wide input range. As shown in FIG. 5, the downlink AGC 82 is preferably provided as an extremely fast, wide dynamic range, highly linear block comprising a single VGA stage 118, a fixed-gain amplifier 120 cascaded with a pair of band-pass filters 122a and 122b, and a directional coupler 124. Inter-stage filters 126a-126c may also be included to reduce cascaded noise.

[74] The downlink AGC VGA 118 preferably has approximately 60 dB of gain variation, and is cascaded with

the fixed gain amplifier 120 to enhance system linearity while minimizing the cascaded noise figure. The BPFs 122a-122b operate to limit VGA noise to the 25 MHz downlink bandwidth, thereby preventing out-of-band signals from capturing the downlink AGC 82 and saturating the downlink path 68 output amplifier 86.

[75] The directional coupler 124, which may be a 17 dB directional coupler, samples the downlink RF signal downstream of the VGA 118. The sample signal is supplied to a feedback path 127 which includes a cascaded RF amplifier 128 and log amplifier 130, and a feedback directional coupler 132 which samples the RF signal within the feedback path 127 and supplies the sample signal to the switching input 96 of the downconverter 88. The RF log amplifier 130 is preferably a variable detection log amplifier controlled by the digital controller 90. The RF log amplifier 130 output supplies a gain control signal to the downlink AGC VGA 118 and the uplink path VGA 76, and may also be supplied to the digital controller 90 to facilitate monitoring and decision functions of the adaptive control algorithm. The feedback path 127 preferably provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 127 closes the AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 118 in the event of inadequate isolation between the antennas 28 and 60. The feedback path 127 also provides a means by which the gain of the downlink AGC 82 can be forced to a low level by the digital controller 90 to maintain stability during system setup, thereby ensuring the detection of weak desired signals without the need for initial system isolation maximization.

[76] The downlink slaved VGA 84 accepts a gain control input from the uplink path AGC 74 to provide a hardware means to adaptively minimize the downlink output power, and thereby implement, in part, the ACB and CAS concepts. The output amplifier 86 increases the downlink RF signal power at the output of the slaved VGA 84 to -26 dBm at the output of the DCA diplexer 70, when the received uplink RF signal power is at a minimum.

[77] Referring now to FIG. 4, the DDP uplink path 66 is designed to receive, process and transmit the entire 824 to 849 MHz uplink channel frequency band. This path 66 comprises the uplink AGC 74, slaved VGA 76 and an output amplifier stage 78, each of which may be cascaded with inter-stage filters 132a, 132b. The uplink AGC 74 functions similarly to the downlink AGC 82. Referring to FIG. 6, the uplink AGC 74 is preferably provided as an extremely fast, wide dynamic range, highly linear block including a single VGA stage 134, fixed-gain amplifiers 136a and 136b cascaded with band-pass filters 138, and a directional coupler 140. Inter-stage filters 142 may also be included to reduce cascaded noise.

[78] The uplink AGC VGA 134 preferably has approximately 60 dB of gain variation, and is cascaded with the fixed gain amplifiers 136 to enhance system linearity. This is important, because the received uplink RF signals are much stronger than received downlink signals. The BPFs 138 following the VGA 134 limit the VGA noise to the uplink band, thereby preventing out-of-band signals from capturing the uplink AGC 74 and saturating the uplink output amplifier 78.

[79] The directional coupler 140, which may be a 17 dB directional coupler, samples the uplink RF signal downstream of the VGA 134. The sample signal is supplied to a feedback path 144 comprising an RF log amplifier 146 and a feedback directional coupler 148 which samples the RF signal within the feedback path 144 and supplies the sample signal to the switching input 96 of the downconvertor 88. The RF log amplifier 146 is a variable detection amplifier controlled by the digital controller 90. The RF log amplifier 146 output supplies a gain control signal to the uplink AGC VGA 134 and the downlink slaved VGA 84, and may also be supplied to the digital controller 90 to facilitate monitoring and decision function of the adaptive control algorithm. The feedback path 144 provides a 25 MHz bandwidth path which operates to ensure system stability by providing substantially instantaneous RF AGC feedback. The feedback path 144 closes the uplink AGC loop, which in turn limits system oscillation by automatically adjusting gain of the VGA 134 in the event of inadequate isolation between the antennas 28 and 60. The feedback path 144 also provides a means by which the gain of the uplink AGC 74 and the downlink slaved VGA 84 can be forced to a low level by the digital controller 90 to maintain stability during system setup, thereby ensuring the detection of weak desired signals in the downlink path 68 without the need for initial system isolation maximization.

[80] The uplink slaved VGA 76 accepts a gain control input from the downlink AGC 82 to provide the hardware means to adaptively minimize the uplink channel output power, and thereby implements, in part, the ACB and CAS concepts. The uplink output amplifier 78 increases the uplink RF signal power to +2 dBm at the port diplexer 72

output. This output power level is necessary to overcome losses associated with the coaxial cable 26.

[81] FIG. 7 is a state diagram illustrating exemplary states and state transitions traversed during operation of the APR 2. Upon application of power to the APR 2, the unit enters an Initialization state 150. In the initialization state 150, the digital controller 90 initializes the hardware (e.g. uplink and downlink IGCs, 92 and 94) and performs a Power-up Built-In Test (PBIT). The results of the PBIT test may be stored in a memory (not shown). Upon successful completion of the PBIT, the APR 2 transitions to the Operational State 152. If the PBIT fails, the APR 2 remains in the Initialize state 150, and in a Standby mode. In addition, a fault message may be generated, for example for display on a suitable display device (not shown).

[82] Upon entering the Operational state 152, an Active mode is selected as an initial default. In the Active mode, the digital controller 90 operates under control of the Adaptive Control Algorithm (ACA) to dynamically adjust the network wireless link 18 for optimum performance. The link status can be displayed on a suitable display (not shown). While in the Operational state 152, the digital controller 90 periodically performs a Continuous Built-In Test (CBIT), the results of which may be stored in memory. Upon detecting a CBIT failure 154, the APR 2 enters the Standby mode of the Operational state 152. A fault message may also be generated, for example for display to the Subscriber. A successful completion of the CBIT 156 maintains the APR 2 in (or returns the APR 2 to)the Active mode. Upon a reset event 158 (e.g. a watchdog reset or a power interruption) the Operational state 152 is exited and

the Initialize state 150 is entered to reset (i.e. re-boot) the APR 2. At any time, status request messages may be received by the APR 2, for example, from an external maintenance system (not shown). Such status requests received while the APR 2 is in the Initialize state 150 may cause the APR 2 to enter the Test state 160. While in the Test state 160, the maintenance system may initiate a download (e.g. of updated software) to the APR 2. The Test state 160 is exited upon a Quit request, for example, from the maintenance system. Status requests from the maintenance system while the APR 2 is in the Operational state 152 allows the maintenance system to extract status information from the APR 2.

[83] As described above, the Adaptive Control Algorithm (ACA) enables the APR 2 to control the subscriber's personal wireless space 6 and the network wireless link 18. Both the subscriber's personal wireless space 6 and the network wireless link 18 are adjusted dynamically based on various parameters obtained through non-intrusive measurements of the wireless signals within the uplink and downlink paths. FIG. 8 is a flow chart illustrating principle operations of an exemplary adaptive control algorithm during initialization and operation of the APR 2.

[84] As shown in Fig. 8, upon start-up, the adaptive control algorithm places the APR 2 into the initialize state 150; sets the signal power levels in the network and local wireless links 18 and 20 to their default values (at step S2); and performs the power-up built-in test PBIT (at step S4). If the PBIT is completed successfully, the adaptive control algorithm transitions the APR 2 to its operational state 152, and attempts to detect the presence of a base station 8a (at step S6). If a base station is

not detected, the adaptive control algorithm sets default values of the signal power levels in the network and local wireless links 18 and 20 (at step S8), and then measures signal and noise levels in each of the uplink and downlink paths to test the quality of each of the network wireless link 18 and local link 20 (at step S10). These test results can be displayed on a suitable display device and may, for example, be used during installation of the APR 2 (e.g. to assist in obtaining proper positioning and alignment of the DDU 22).

[85] If the base station is detected (at step S6), the adaptive control algorithm attempts to detect a base station control channel within the network wireless link 18 (at step S12). If the base station control channel is detected at step S12, the adaptive control algorithm attempts to detect a subscriber control channel in the local wireless link 20 (at step S14). If the subscriber control channel is detected at step S14, the adaptive control algorithm uses measured signal power levels in the uplink and downlink paths to adjust transmit power levels in each of the network wireless link 18 and the local wireless link 20, in order to optimize performance (at steps S16 and S18).

[86] If control channels are not detected in either of the network wireless link 18 or the local wireless link 20 (at Steps S12 and S14), the adaptive control algorithm attempts to detect a voice channel in the local wireless link 20 (at step S20). If a subscriber voice channel is detected at step S20, the adaptive control algorithm then attempts to detect a voice channel in the network wireless link 18 (at step S22). If a base station voice channel is detected at step S22, the adaptive control algorithm

returns to steps S16 and S18 to optimize the performance of the uplink and downlink paths. Otherwise, if voice channels are not detected in either the network wireless link 18 or the local wireless link 20 (at steps S20 and S22), then the adaptive control algorithm returns to steps S8 and S10 to set the default power levels in the uplink and downlink paths, and measure signal and noise levels to test the quality of each of the network and local wireless links 18 and 20.

[87] As described above, transmit signal power in the network wireless link 18 is adjusted (at step S16 of Fig. 8) based on the received signal power of downlink RF signals within either the base station control channel and/or voice channel. Similarly, the subscriber's personal wireless space 6 is adjusted by adjusting the transmit power of downlink RF signals within either the control channel and/or the voice channel, based on the received signal power of uplink RF signals transmitted by the subscriber's wireless communications device 16. This process of continuous adjustment of the network and local wireless links 18 and 20 enables continuous optimization of the performance of each of these links, and, within the subscriber's personal wireless space 6, implements the adaptive coverage breathing and coverage area signature functionality of the present invention. Periodic detection of base station and subscriber control and voice channels (at steps S12, S14, S20 and S22 of Fig. 8) enables the APR 2 to adaptively accommodate multiple subscriber wireless communications devices 16 within the subscriber's personal wireless space 6.

[88] Thus it will be seen that the present invention provides an apparatus that enables an individual subscriber

to cost-effectively access and provide high quality wireless communications services, independently of a location of the subscriber.

[89] The embodiment(s) of the invention described above is(are) intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.